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SULFUR DIOXIDE

Occupational Exposure

DEPARTMENT OF LABOR

Occupational Safety and Health Administration

[29 CFR Part 1910]

[Docket No. H–039]

OCCUPATIONAL EXPOSURE TO SULFUR DIOXIDE

Notice of Proposed Rulemaking

Pursuant to sections 6(b) and 8(c) of the Occupational Safety and Health Act of 1970 (the Act) (84 Stat. 1593, 1599; 29 U.S.C. 655, 657), and Title 29, Code of Federal Regulations (CFR) Part 1911, it is proposed to amend 29 CFR Part 1910 by deleting the present standard for sulfur dioxide (SO_2) contained in 29 CFR 1910.1000, Table Z–1, and by adding a new standard for occupational exposure to sulfur dioxide as 29 CFR 1910.1030. This standard would apply to all employments in all industries covered by the Act, including "general industry", construction, and maritime. In addition, pursuant to section 4(b)(2) of the Act (84 Stat. 1592, 29 U.S.C. 653), if the new standard, when promulgated, is determined to be more effective and appropriate than corresponding standards now applicable to the maritime and construction industries contained in Subpart B of Part 1910, Parts 1915, 1916, 1917, 1918, and 1926 of 29 CFR, the new sulfur dioxide standard will supersede the corresponding maritime and construction standards for exposure to sulfur dioxide. Appropriate conforming amendments will be made in Subpart B of Part 1910, and amendments to delete the superseded standards will be made in 29 CFR 1926.55 and in similar sections of Parts 1915–1918.

The accompanying document is a proposal issued pursuant to section 6(b) of the Act. The notice requests the submission of written comments, data, and arguments from any interested persons on a variety of issues addressed or implicit in the proposal. In addition to filing comments, interested persons may also file objections to the proposal requesting an informal hearing with respect thereto.

The proposed standard contains a requirement limiting employee exposure to an 8-hour time-weighted average exposure concentration of 2 parts sulfur dioxide per million parts air (5.23 mg/m^3), together with a ceiling limit of 10 ppm (26.12 mg/m^3) as measured over a sampling period of 15 minutes. The proposal also provides for employee exposure measurements, methods of compliance, personal protective clothing and equipment, training, medical surveillance, employee observation of exposure measurements, and recordkeeping.

The issues raised in the proposal include, among others, the following:

(1) Whether proposed permissible exposure limit of 2 ppm based on an 8 hour time-weighted average for a 40 hour week, and the ceiling limit of 10 ppm as measured over a sampling period of 15 minutes is appropriate;

(2) To what extent are there hypersusceptible employees in the working population and to what extent, if any, should such employees be considered in establishing a standard for occupational exposure to any substance, in this case sulfur dioxide;

(3) To what extent, if any, are there chronic effects of sulfur dioxide exposure;

(4) To what extent, if any, does sulfur dioxide promote cancer;

(5) Should OSHA seek in one standard to regulate one substance, SO_2, and cover other sulfur dioxide decay products in subsequent standards; or should OSHA attempt to set one standard inclusive of sulfur dioxide and its decay products.

(6) The provisions for, among other things, employee exposure measurements, methods of compliance, signs and labels, medical surveillance, protective equipment and clothing, training, and recordkeeping;

(7) The environmental and inflationary impacts of this proposal;

(8) The feasibility of complying with a TWA of 2 ppm and a ceiling of 10 ppm; and

(9) The application of the recordkeeping and similar requirements to small businesses and those with highly transient work forces.

In the development of this proposal, OSHA has considered recommendations contained in the document entitled "Criteria for a Recommended Standard . . . Occupational Exposure to Sulfur Dioxide," which was developed for the Secretary of Labor by the National Institute for Occupational Safety and Health (NIOSH), Department of Health, Education, and Welfare. Further, OSHA has reviewed and considered numerous reference works and scientific journal articles. (See References section of this Notice for partial listing of sources).

I. Background

A. *General.* Sulfur dioxide (SO_2), Chemical Abstracts Service Registry Number 7446095, is a colorless, nonflammable, irritant gas having the odor of burning sulfur. It is formed whenever sulfur is burned in the air. It is readily liquified and is shipped as a liquified gas in steel cylinders under its own vapor pressure (about 35 psig at 70° F).

Industrially, sulfur dioxide is used in the manufacture of sodium sulfite and as an intermediate in the manufacture of sulfuric acid. It is also used in refrigeration, bleaching, fumigating, and preserving operations, and as an antioxidant in the melting, pouring, and heat treatment of magnesium. In addition to its wide range of uses in industry, sulfur dioxide is also released as an unwanted by-product of processes such as smelting of ores, combustion of coal or fuel oils containing sulfur as an impurity, paper manufacturing, and petroleum refining.

There are numerous chemical reactions which occur in the workplace due to the presence of sulfur dioxide. In the presence of oxygen and water, ferrous sulfate ($FeSO_4$) catalyzes the direct oxidation of sulfur dioxide to sulfuric acid. Also some metal oxides, such as magnesium oxide, ferric oxide, zinc oxide, manganic oxide, cerous oxide, and cupric oxide oxidize sulfur dioxide directly to sulfate compounds. Sulfides are also formed if the metal ions are not reduced to a lower valence state. Sulfur dioxide is also known to react with the halogens to produce sulfuric acid and with water to firm sulfuric acid or the salts of sulfuric acid. Experiments have shown that SO_2 may act as either an oxidizing or reducing agent at room temperoture. As a reducing agent, SO_2 gas reacts slowly with oxygen at 400 degrees centigrade to form sulfur trioxide. However, with a catalyst, such as finely divided platinum, charcoal, vanadic oxide, graphite, chromic oxide, ferric oxide, or nitrogen oxides, oxidation to SO_3 may occur at room temperatures. (Nitrogen oxides are used as catalysts in the chamber process of manufacturing sulfuric acid from sulfur dioxide.)

Sulfur dioxide is a common workplace hazard. The National Institute of Occupational Safety and Health (NIOSH) estimates that as many as 500,000 workers could have potential exposure to the substance. It is also a community air pollution problem.

B. *History of Regulations.* In 1945, Cook compiled a summary of standards which listed the maximum allowable concentration (MAC) of sulfur definite discomfort in exposed workers. The tentative TLV of 5 ppm was adopted in 1958.

In 1968, the ACGIH further documented the 5 ppm TLV and included Greenwald's human and animal studies and information of acute upper respiratory irritation and nosebleeding which had occurred in workers exposed to 10 ppm sulfur dioxide, but not at a level of 5 ppm.

The present Occupational Safety and Health Administration (OSHA) standard for exposure to sulfur dioxide, found in 29 CFR 1910.1000, Table Z–1, was adopted from the applicable standard under the Walsh-Healey Act (41 U.S.C. 35 *et seq.*), incorporating the ACGIH on 29 May 1971.

In June 1974, NIOSH published the document entitled "Criteria for a Recommended Standard . . . Occupational Exposure to Sulfur Dioxide." In this document, NIOSH recommended a permissible exposure limit of 2 ppm time-weighted average (TWA) to control the effects of exposure to sulfur dioxide. This recommendation was based on reports of irritant effects, pulmonary function reduction, and also the possible cancer "promoting effects" of sulfur dioxide in workers. Although not itself a carcinogen, sulfur dioxide may promote cancer by lowering the body's defenses in the respiratory system to the penetration and retention of certain carcinogens.

II. Health Implications of Occupational Exposure to Sulfur Dioxide

Sulfur dioxide is a recognized human irritant. Its irritant properties are due to the rapidity with which it forms sulfurous acid on contact with moist membranes. An estimated 90 percent of all SO_2 inhaled is absorbed in the upper respiratory passages with only slight

penetration in the lower respiratory tract.

Sulfur dioxide exerts its toxic influence on humans through acute and possibly chronic effects. Acute symptoms of exposure are eye, mucosal, and upper respiratory irritation. Potential chronic effects include nasopharangitis, reduction of pulmonary function, increased resistance to air flow and promotion of cancer.

A. *Chronic effects.* Chronic effects of sulfur dioxide exposure may result from repeated bronchoconstriction. While bronchoconstriction is not itself a chronic effect, it is believed that continual insults actually lead to substantial permanent pulmonary impairment in excess of the normal gradual decrease in pulmonary function due to the aging process.

There are, unfortunately, only limited epidemiological studies and a few animal studies which attempt to uncover any chronic effects due to sulfur dioxide exposure.

1. *Epidemiological Studies.* In 1932, Kehoe *et al.* published the results of a study on the effects of chronic exposure to relatively pure sulfur dioxide gas, which resulted from the evaporation of liquid sulfur dioxide used as a refrigerant. The study examined two groups of 100 male workers. The exposed group had a mean duration of occupational exposure to sulfur dioxide of 3.8 years. Average exposure concentrations during the period of the study (1929–1930) were 20–30 ppm with a range between 10 and 70 ppm. However, prior to 1927, exposures in the plant averaged 80–100 ppm with frequent fluctuations. The control group, age-matched with the exposed group, had no known exposure to sulfur dioxide or any other noxious gases, fumes, or dusts.

Each of the 200 subjects was questioned in detail as to the length and nature of his exposure to sulfur dioxide, and complete physical examinations, including chest x-rays, blood tests, and urinalysis were conducted. Kehoe found a significantly higher incidence of nasopharangitis, alteration of the senses of small and taste, and an increased sensitivity to other irritants in the exposed group as compared to the control group. The exposed group also exhibited a higher incidence of abnormal urine acidity, a tendency to increased fatigue, dyspnea on exertion, and abnormal reflexes.

Kehoe concluded that there was "no demonstrable association between frequency or severity of initial symptoms and frequency of heavy exposure, nor was there any relation between exposure and the frequency and severity of symptoms arising from the customary exposure." However, he found a positive correlation between frequency of heavy exposure and the presence of symptoms of abnormal acid accumulation in body tissues, and "increased fatigability during the period of employment and shortness of breath on exertion."

Kehoe also noted that although the incidence of colds was not significantly different between the two groups, the exposed group appeared to have colds of longer duration than the control group. In all other respects, Kehoe found no significant differences between the exposed group and controls.

Kehoe's findings suggest that the primary observed effects of exposure to sulfur dioxide are acute. However, the higher incidence of nasopharangitis, the tendency to increased fatigue, shortness of breath on exertion, and dyspnea indicate that at concentrations above the present standard of 5 ppm, there are chronic effects in the form of physical symptoms. Some inherent problems exist with this study, however; First, this study was made in 1932, and sampling techniques, methods of analysis, x-ray techniques and ability to measure pulmonary function have greatly improved. Factors such as general conditions within the plant, temperature extremes, the percent of the work force who were smokers, and even the length of the average work day and the work week were not clearly defined. Such factors could have affected his results.

A study by Anderson in 1950 analyzing the effects of sulfur dioxide exposures on Iranian oil refinery workers found no evidence of adverse health effects from exposure to sulfur dioxide. This study, however, has been strongly criticized because it made no mention of any effects such as pulmonary irritation, coughing, or nasal irritation.

A study by Skalpe (1964) reported on the chronic effects of sulfur dioxide exposure among workers in Norwegian paper-pulp mills, where exposures ranged from 2–36 ppm. In combination with the sulfur dioxide were agents such as chlorine, chlorine dioxide, hydrogen sulfide, and some organic sulfides including mercaptans. Unlike the preceding studies, the research was begun in response to complaints of chronic coughing among workers in the digester plant. He attempted to determine whether there was a higher incidence of respiratory disease among these workers than among comparable groups of unexposed workers.

The results of Skalpe's study indicated a significantly higher frequency of respiratory disease symptoms such as coughing, expectoration, and dyspnea, among the exposed group, especially in those workers under 50 years of age, where employment exposure duration was shortest. However, among those workers over 50, there appeared to be no significant difference in symptoms between the exposed group and the controls. Further, vital capacity values showed no difference between exposed and nonexposed workers, which could suggest that chronic pulmonary disease does not result from chronic exposure to sulfur dioxide. According to the author, the most likely explanation for the disparity in symptoms between the under-49 age group and the over-50 group is that, because respiratory disease is rare in younger age groups, the effect of small external insults was easier to detect than in the older age groups where respiratory disease from other causes is more common and small additions due to sulfur dioxide exposure would tend to be less noticeable. Another possible explanation, although not suggested by the author, is that younger workers with respiratory disease remove themselves from sulfur dioxide exposure before they reach the age of 49.

The preliminary reports by Archer of NIOSH and T. Smith of the University of Utah suggest that occupational exposure to sulfur dioxide may lead to the reduction of pulmonary function. The investigators examined two groups for effects of exposure to sulfur dioxide. The workers from a copper smelter served as the exposed group and those from the mine haulage truck maintenance shop, which was located 15 miles from the smelter, served as the control. Measurements were made for Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV_1). Utilizing the British Medical Research Council questionnaire, each participant was questioned on a history of cough, coughing up phlegm, chest noises and shortness of breath among other things. Personal air samples were collected when workers were not wearing respirators to accurately determine exposures to sulfur dioxide and particulates.

The results of the measurements indicated that most of the workers in the smelter were exposed to less than 2 ppm TWA of sulfur dioxide and as high as approximately 1 mg/m^3 of particulates. The particulates in the smelter were found to be a mixture of various metal oxides including arsenic, silicates, sulfates, and sulfites (including iron sulfite). The control work environment was determined to be similar in particulate concentrations without sulfur dioxide, although the components of the contaminants were quite different. The control population was exposed to nitrogen oxides, aldehydes and benzene soluble particulates. These contaminants were not found in measurable amounts in the smelter. The results of the questionnaires indicate an overall trend for the smelter workers to have a greater percentage of chronic respiratory disease than the controls. However, this trend is statistically significant only among non-whites, and tends to be reversed among "light and former" smokers.

The results of the pulmonary function tests indicate that the smelter workers show a 4.8 percent greater reduction of FVC and FEV_1 as compared to the controls. The authors found this reduction to be statistically significant. It appears that the control population was also exposed to substances that might reduce the pulmonary function, which tends to raise the control values higher than the general population. It should be noted that other substances such as iron sulfites, which are protein reactors, might also be responsible for the reduction of pulmonary function. While this study is preliminary in nature and requires a thorough examination by the scientific community, our tentative judgment is that sulfur dioxide exposure may well lead to reduced pulmonary function.

In order to determine whether the observed pulmonary function reduction also results in an excess mortality due to lung disease, OSHA has reviewed the mortality studies of copper smelter workers. According to the Le and Fraumeni and the Rencher and Carter studies, there was no excess of mortality due to lung disease, influenza and pneumonia in the copper smelter workers.

OSHA requests comments on the significance of the observed reduction of pulmonary function during the employee's lifetime, on the finding of no excess mortality due to lung disease, and on any related issue.

2. *Animal Studies.* A number of researchers have investigated the effects of sulfur dioxide inhalation on experimental animals.

Prokhorov and Rogov (1959) studied the histopathological and histochemical effects of prolonged exposure of rabbits up to 76 ppm sulfur dioxide, and also to combinations of sulfur dioxide and carbon monoxide, for periods of 30 hours per week for 13 weeks.

The investigators found that exposure to sulfur dioxide alone resulted in edema of the myocardial muscle fibers, capillary enlargements, and perivascular hemorrhages. Further, exposure to sulfur dioxide produced dystrophic changes in the epithelial cells of the renal tubules. It also produced alveolar epithelial cell proliferation in the lungs. The authors found that many of these changes were more pronounced when exposures were to both sulfur dioxide and carbon monoxide.

In 1970 Alarie *et al.* reported the results of a study in which guinea pigs were exposed almost continuously (22 hours per day, 7 days per week) to approximately 0.1, 1.0, and 5 ppm sulfur dioxide for one year. Thorough pulmonary function measurements, including tidal volume, respiratory rate, minute volume, dynamic compliance, pulmonary flow resistance and carbon monoxide uptake, indicated no detrimental changes attributable to sulfur dioxide exposure. Hematological and light microscopic tissue studies (electro-microscopic examination was not performed) also failed to show any adverse effects in body weight, growth, and survival.

In a subsequent study, Alarie reported on the long-term effects of sulfur dioxide on young cynomolgus monkeys. The exposure was 24 hours per day for 78 weeks. Levels of exposure ranged from 0.1 to 5 ppm. Control groups exposed to fresh air for the same duration of time were also included.

Evaluations were made on mechanical properties of the lung, arterial blood tension, lung histology, hematological and blood biochemical indices, and organ histology. No deleterious effects could be attributed to concentrations of 0.1 to 5 ppm of sulfur dioxide.

Alarie also completed several studies on long-term continuous exposure to sulfur dioxide in combination with other mixtures, such as fly ash and sulfuric acid mists. In all experiments both guinea pigs and cynomolgus monkeys were used. Monkeys were grouped into sets of 9 animals, with one group serving as a control. Guinea pigs were divided into groups of 50, likewise with one group serving as a control. Exposure duration was 24 hours per day, 7 days per week, for 78 consecutive weeks for the monkeys and 52 consecutive weeks for the guinea pigs. Exposure conditions and biological measurements for both animal types were the same. They consisted of pulmonary function tests, including: measurements of the mechanical properties of the lungs and respiratory system, the distribution of pulmonary ventilation, diffusing capacity of the lung, and arterial blood gas tension. Hematological, serum biochemical determinations, body weight, and survival measurements were also taken. At termination of exposure both animal groups were killed and necropsies were performed.

The results of the combined sulfur dioxide and fly ash exposures were that no detectable deleterious effects could be attributed to either agent. It also appeared that when pulmonary infection is low, sulfur dioxide is without any "beneficial" effect, and when pulmonary infection is high, animals exposed to sulfur dioxide show a reduced incidence and severity of symptoms.

Deleterious effects resulted from the combined sulfur dioxide and sulfuric acid mist exposures. The author concluded that these effects could be attributed to exposure to sulfuric acid mists at concentrations between 0.1 and 1 mg/m^3 regardless of particle size. Effects were small and variable at 0.1 and more pronounced at 1.0 mg/m^3 of the mist.

Alarie further elaborated upon his finding in a study in which exposure consisted of combinations of sulfur dioxide, sulfuric acid mists, and fly ash mixtures. All conditions were the same as for previous experiments, and concentrations of the substances were consistent with previous experiments. The results of this study were that deleterious histopathological changes of the same nature as those in the sulfuric acid mist experiments were found in pulmonary tissues of both animal types at the same exposure levels.

From the findings of all his studies, Alarie conclude that no detrimental effects were detected in either animal type from long-term exposure to sulfur dioxide alone or in the presence of fly ash at levels ranging from 0.1–5 ppm.

Moreover, the deleterious effects detected from the exposures to mixtures of sulfur dioxide, fly ash, and sulfuric acid mist, were attributable to the presence of the sulfuric acid mist alone.

Amdur has also completed several studies on sulfur dioxide exposure alone and in combination with other substances. In a current EPA report, "Toxicology of Atmospheric Sulfur Dioxide Decay Products", she presented her views of effects due to exposure to sulfur dioxide, including the effects of the decay products of sulfur dioxide, such as SO_3, SO S_2O_5, S_2O_7, SO_4, H_2SO_3, H_2SO_4, SO_4 compounds and SO_3 compounds. She suggests on the basis of studies which she performed with Pattle and Bustueva, that sulfuric acid mists, and various sulfate and sulfite particulates coupled with sulfur dioxide exposures, should be considered in setting an air quality standard. In fact, she concluded that these products of sulfur dioxide decay present more of a hazard than exposure to sulfur dioxide alone.

In reviewing the literature in this EPA report, Amdur concluded that data on mass concentrations alone are an insufficient basis on which to predict irritant potency, because particle size plays an important role in determining the potency of sulfuric acid particles, and, secondly, because particulate oxidation products of sulfur dioxide are generally much more potent irritants than the sulfur dioxide gas alone.

B. *Acute effects.* Acute exposures to concentrations of SO_2 ranging from 10 to 50 ppm have been reported to cause irritation of the nose and throat, and rhinorrhea, choking, and coughing. These symptoms are sufficiently disagreeable that most persons will not tolerate them for more than 15 minutes. These concentrations within a time frame of 5–15 minutes, have caused temporary reflex bronchoconstriction with increased pulmonary resistance to air flow.

There have also been reports, such as those in the Galea report, of the development of symptoms comparable to those of bronchial asthma following acute exposure to sulfur dioxide concentrations.

Sulfur dioxide gas is also an eye irritant, causing burning and lacrimation, although actual eye injury from the gas occurs only at very high concentrations. Exposure to liquid sulfur dioxide from pressurized containers is capable of causing corneal burns and opacification of the cornea resulting in a loss of vision. Liquid sulfur dioxide also produces skin burns upon contact due to the freezing effect of the rapidly evaporating liquid.

Numerous experimental studies on human subjects who had no occupational exposure have examined the effects of sulfur dioxide inhalation on the respiratory mechanism.

Frank *et al.* (1962) reported no detectable changes in pulmonary flow resistance or peak flow rate in adult males exposed to 1 ppm sulfur dioxide. Exposures lasted for 10–30 minutes and were spaced at least one month apart.

Snell and Luchsinger (1969), however, reported a small, but statistically significant, decrease in maximum expiratory flow from the level of one-half vital capacity in a group of 9 physicians and technicians exposed to 1 ppm of sulfur dioxide for 15 minutes. Because these studies were conducted under controlled laboratory conditions, with a forced inhalation technique, this response may have been caused by anticipation, irritation of the mucous membranes, and other factors. Also, the reaction was reversed upon cessation of sulfur dioxide exposure, indicating that the reported response was acute.

In 1964, Frank, *et al.* found a 39 percent increase in pulmonary flow resistance in male subjects exposed to 5 ppm

sulfur dioxide for 10 minutes. Frank's experiments involved the inhalation of a series of increasing concentrations of sulfur dioxide. The investigators found that only one of the 11 volunteers had any increase in airway resistance at the 1–2 ppm level, but that there was a 72 percent increase in airway resistance at the 10–16 ppm level.

One of the chief limitations of this experiment is that the number of subjects involved was too small to establish a trend. Also, Frank's subjects were not examined for evidence of any chronic effect from sulfur dioxide inhalation. The increase in pulmonary flow resistance was an acute response attributable to the irritation of the nasal mucosa, which in turn reflexively narrowed the subject's airways, producing the flow resistance.

Weir, *et al.* (1969) exposed 4 groups of 3 young adult males to low levels of sulfur dioxide continuously for 120 hours. The investigators found no evidence of dose-related changes in subjective complaints, clinical evaluation, or pulmonary function measurements at levels of 0.3 and 1 ppm. However, at 3.0 ppm there was evidence of significant, but minimal, reversible decreases in small airway conductance and compliance.

Nadel, *et al.* (1965) found that inhalation exposure of 4–6 ppm for 10 minutes by male subjects resulted in an increase in airway resistance. This effect could be completely prevented by injection of atropine subcutaneously. Nadel's findings support the theory that increased airway resistance following sulfur dioxide inhalation may be due to a reflex bronchoconstrictive effect caused by irritation of the nasal mucosa. This theory is also supported by the fact that the reaction diminishes as a function of the level of sulfur dioxide to which the subjects were exposed, and that the reaction reverts to normal upon cessation of exposure.

Burton *et al.* exposed 10 healthy men (age ranges from 25–34 years) to low concentrations (1.2–3.0 ppm) of sulfur dioxide in air. Five of the men were smokers and five were not. The results of the study showed that low concentrations of sulfur dioxide in the air did not result in immediate physiologic effects on measures of pulmonary mechanics in the volunteers. Also a gas-aerosol synergism for sulfur dioxide and inert aerosols could not be demonstrated.

In 1970, Melville studied changes in specific airway conductance of volunteers exposed to levels of 2.5, 5, and 10 ppm, SO_2 for one hour. Melville observed a more pronounced decrease in specific airway conductance when inhalation was through the mouth rather than through the nose, at these levels. However, at 10 ppm, the same degree of reduction of conductance was noted regardless of the method of inhalation. The author suggested that at levels up to 5 ppm, the nasal passages absorb some of the inhaled sulfur dioxide, and thereby diminish the stimulation of sensitive receptors in the larynx, trachea, and bronchi. Further, at all levels the greatest percentage change (irrespective of the path of entry) was seen when exposures reached approximately 5 minutes. However, there was no significant decrease in specific airway conductance after the first 5 minutes of exposure. Melville also noted that there were no detectable adverse effects after an hour's exposure to sulfur dioxide at levels up to 10 ppm.

C. *Hypersusceptibility and Adaptation.* In reviewing experimental studies on sulfur dioxide exposure, two phenomena repeatedly manifest themselves, i.e., hypersusceptibility and adaptation.

Hypersusceptibility may be defined as acute sensitivity or overreaction to sulfur dioxide exposure at concentrations at which most persons have only a mild or no response. The mechanism of hypersusceptibility is unknown, and in some cases the reactions elicited by such individuals may not be reversible.

In 1969, a study by Burton *et al.* estimated that such "hyperreactors" may comprise 10–20 percent of the healthy young adult population. The hyperreactive responses can occur with single exposures to sulfur dioxide. Apparently, many such persons voluntarily remove themselves from surroundings involving sulfur dioxide exposure, as was indicated by the Ferris *et al.* study.

Adaptation may be defined as a physiological compensation for the effects of sulfur dioxide. It is thought to occur through depression of tracheobronchial nerve reflexes, coupled with a direct action on bronchial smooth muscles. A prolonged decrease in airway conductance (caused by the tracheobronchial nerve depression) may have adverse effects on pulmonary function.

Several studies have shown evidence of rather rapid adaptation to sulfur dioxide, especially on respiratory mechanics. In 1953, Amdur reported that 2 men who worked in atmospheres containing 10 ppm sulfur dioxide showed no changes in respiratory rate, tidal volume, or pulse rate at 5 ppm exposures. Frank *et al.* also demonstrated that initial coughing and irritation subsided after 5 minutes of exposures to 5 and 13 ppm SO_2.

Melville's study on adaptation found no adverse physical effects attributable to adaptation to sulfur dioxide exposure.

D. *Carcinogenic Implications.* Although no study has implicated sulfur dioxide alone as a carcinogen, the suggestion has been made by some researchers that it may have a "promoting" effect on man when he is exposed simultaneously to a carcinogenic agent such as inorganic arsenic or benzo(a)pyrene. It has been postulated that due to the irritant properties of sulfur dioxide, the pulmonary clearance mechanism may be retarded, thus enhancing the retention of such agents. The only mortality study available on this subject is one by Lee and Fraumeni.

Lee and Fraumeni reviewed the total mortality among workers in smelters, and found as much as an 8-fold excess in instances of respiratory cancer as compared with that of the white male populations of the same states. Their findings indicate that agents in the smelters, such as arsenic, may be responsible for the excess. However, the Lee and Fraumeni data also indicate that as the levels of both sulfur dioxide and inorganic arsenic increase, the incidence of respiratory cancer also increases, except that employees with heavy arsenic exposure and moderate to heavy sulfur dioxide exposure were most likely to die of respiratory cancer.

Other investigators have attempted to establish a link between sulfur dioxide inhalation and carcinogenesis in animals. In 1967, Peacock and Spence exposed male and female spontaneous tumor-susceptible mice to 500 ppm sulfur dioxide for 5 minutes. The exposures were repeated 5 days per week for 300 days. The observed distribution of tumors (both malignant and nonmalignant) was not shown to be satistically different from those of the controls. The authors concluded, however, that sulfur dioxide exposures at this level accelerated the onset of neoplasia as a result of the initial, essentially inflammatory reaction caused by the sulfur dioxide. However, these effects were not considered to be sufficient to justify the classification of sulfur dioxide as a chemical carcinogen.

Laskin, *et al.* (1970) reported the induction of bronchogenic squamous cell carcinomas in rats exposed to sulfur dioxide in combination with benzo(a)-pyrene. Laskin's results suggest a "promoting effect" for sulfur dioxide because sulfur dioxide and benzo(a)pyrene when inhaled singly by rats have failed to produce bronchogenic carcinomas.

OSHA invites comment on whether sulfur dioxide should be treated as a cancer promoting substance; and if so, what effect this should have on the way in which sulfur dioxide is regulated in the workplace.

III. Pertinent Legal Authority

The primary purpose of the Act is to assure so far as possible safe and healthful working conditions for every working man and woman. One means prescribed by Congress to achieve this goal is the authority vested in the Secretary of Labor to set mandatory safety and health standards. The standards setting process under section 6 of the Act is an integral part of an occupational safety and health program in that the process permits the participation of interested parties in consideration of medical data, industrial processes and other factors relevant to the identification of hazards. Occupational safety and health standards mandate the requisite conduct or exposure level and provide a basis for ensuring the existence of safe and healthful workplaces.

The Act provides that:

> The Secretary, in promulgating standards dealing with toxic materials or harmful physical agents under this subsection, shall set the standard which most adequately assures, to the extent feasible, on the basis of the best available evidence, that no employee will suffer material impairment of health or functional capacity even if such

employee has regular exposure to the hazard dealt with by such standard for the period of his working life. Development of standards under this subsection shall be based upon research, demonstrations, experiments, and such other information as may be appropriate. In addition to the attainment of the highest degree of health and safety protection for the employee, other considerations shall be the latest available scientific data in the field, the feasibility of the standards, and experience gained under this and other health and safety laws. (Section 6(b)(5))

Sections 2(b) (5) and (6), 20, 21, 22, and 24 of the Act reflect Congress' recognition that conclusive medical or scientific evidence including causative factors, epidemiological studies or dose-response data may not exist for many toxic materials or harmful physical agents. Nevertheless, standards cannot be postponed because definitive medical or scientific evidence is not currently available. Indeed, while final standards are to be based on the base available evidence, the legislative history makes it clear that "it is not intended that the Secretary be paralyzed by debate surrounding diverse medical opinion." House Comm. on Education and Labor, H.R. Rep. No. 91–1291, 91st Cong., 2d Sess. 18 (1970).

This congressional judgment is supported by the courts which have reviewed standards promulgated under the Act. In sustaining the standard for occupational exposure to vinyl chloride (29 CFR 1910.1017), the U.S. Court of Appeals of the Second Circuit stated that "it remains the duty of the Secretary to act to protect the workingman, and to act even in circumstances where existing methodology or research is deficient." "Society of Plastics Industry, Inc v. Occupational Safety and Health Administration" 509 F. 2d 1301, 1308 (2d Cir. 1975), cert. denied, ------ U.S. ------, 95 S. Ct. 1998, 44 L Ed. 2d 482 (1975).

A similar rationale was applied by the U.S. Court of Appeals for the District of Columbia Circuit in reviewing the asbestos standard (29 CFR 1910.1001). The Court stated:

> some of the questions involved in the promulgation of these standards are on the frontiers of scientific knowledge, and conseqeuntly as to them insufficient data is presently available to make a fully informed factual determination. Decision-making must in that circumstance depend to a greater extent upon policy judgments and less upon purely factual analysis.

"Industrial Union Department, AFL–CIO v. Hodgson," 499 F. 2d 467, 474 (D.C. Cir. 1974).

In setting standards, the Secretary is expressly required to consider the feasibility of the proposed standards. Senate Comm. on Labor and Public Welfare, S. Rep. No. 91–1282, 91st Cong., 2d Sess., p. 58 (1970). Nevertheless, considerations of technological feasibility are not limited to devices already developed and in use. Standards may require improvements in existing technologies or require the development of new technology. "Society of Plastics Industry, Inc. v. Occupational Safety and Health Administration," *supra* at 1309.

Where appropriate, the standards are required to include provisions for labels or other forms of warning to apprise employees of hazards, suitable protective equipment, control procedures, monitoring and measuring of employee exposure, employee access to the results of monitoring, and appropriate medical examinations. Moreover, where a standard prescribes medical examinations or other tests, they must be made available at no cost to the employees (Section 6(b)(7)). Standards may also prescribe recordkeeping requirements where necessary or appropriate for enforcement o fthe Act or for developing information regarding occupational accidents and illnesses (Section 8(c)).

IV. The Proposal

The following section discusses and analyzes some of the significant issues of the proposed standard for occupational exposure to sulfur dioxide.

A. *Permissible exposure limits.*—1. *Time-weighted average.* Chronic pulmonary effects have been tentatively reported by Archer and Smith at 2 ppm, and perhaps lower. It is believed that these chronic effects may result from repeated insults, even at levels as low as 2.5 ppm, which cause bronchoconstriction. In addition, the present data suggest sulfur dioxide may promote cancer and it is clear that sulfur dioxide decay products also present a significant workplace hazard.

Based upon the foregoing, it appears that the present 5 ppm TWA does not adequately protect workers from the effects resulting from chronic exposure to sulfur dioxide. We believe, however, that the proposed 2 ppm TWA will significantly minimize potential chronic effects resulting from exposures to sulfur dioxide. We recognize that, based solely upon health considerations, the Smith and Archer data suggest that employee exposures should be reduced to 2 ppm, and perhaps lower. Yet, based upon current feasibility data, it appears that employee exposures cannot be feasibly reduced below 2 ppm TWA. The extensive survey of the smelting industries by W. Wagner of NIOSH indicates that most of the operations can be controlled to meet the proposed permissible exposure limit, even though some of the operations may not be controlled fully. In these circumstances, it is OSHA's judgment that the affected industries can feasibly comply with the proposed permissible exposure limit and that employees will be provided significant protection from the hazards associated with sulfur dioxide.

2. *Ceiling Limit.* Based on the available scientific evidence, it appears that acute symptoms such as severe eye and upper respiratory irritation appear in many workers at approximately 20 ppm. Milder irritation may appear in workers at levels beginning at approximately 10 ppm.

OSHA believes that it is necessary to establish a ceiling limit of 10 ppm, as measured over a sampling period of 15 minutes, to curtail the acute effects due to exposures to sulfur dioxide. In addition, it is thought that this ceiling will have a secondary effect of reducing the effects of the decay products of sulfur dioxide by controlling the source of such contaminants.

As with the proposed 2 ppm TWA, we believe that the proposed 10 ppm ceiling level represents an appropriate consideration of the health and feasibility factors. Thus, a 10 ppm ceiling will protect normal employees from the severe effects of exposure and provide significant protection against the mild symptoms associated with sulfur dioxide exposure. Moreover, it appears that the proposed ceiling will be feasible for most employers in most job classifications.

B. *Action level.*—In addition to time-weighted average and ceiling limits, the proposed standard prescribes an action level which is a concentration of SO_2 equal to one-half of the TWA, at or above which certain precautionary measures such as exposure measurements and medical surveillance must be initiated.

The proposed action level for SO_2 is any concentration greater than or equal to 1 part per million (2.61 mg/m^3). Like the TWA, the action level is based on an eight-hour time-weighted average.

In OSHA's judgment, two kinds of uncertainties can affect an employer's efforts to be reasonably confident of the results of his exposure measurement program. First, he must know if his sampling and analysis accurately inform him of his employee's actual exposure level on the day of measurement. Assuming that an employee's exposure has been properly measured, an employer can be reasonably sure of the employee's exposure on the day of measurement.

Second, the employer must also know whether the measured exposure level on one day is indicative of exposure levels on days he does not measure. It is known that the level of contamination in occupational environments varies from day to day in a random fashion. This variation in levels is unavoidable; it is only minimally related to the precision and accuracy of the method of measurement, and does not include variations due to changes in work processes or controls.

OSHA has determined statistically that even though all measurements of exposure level may fall below the permissible limit, some possibility exists that on unmeasured days the employee's actual exposure may exceed the permissible limit. Leidel, N.A. *et al.* "Exposure Measurement Action Level and Occupational Environmental Variability," DHEW, PHS, CDC, NIOSH, DLCD (August 1975). Above one half the permissible limit, i.e., the action level, the statistical risk is such that an employer can not reasonably be confident that his employees may not be overexposed. Therefore, requiring exposure measurements to begin at the action level provides the employer with a reasonable degree of confidence in the results of his measurement program.

In view of these considerations and in order to provide maximum employee protection, the proposal would also re-

quire the employer to commence medical surveillance at the action level.

C. *Effects of overtime on exposure.*—The permissible TWA is based upon an 8-hour concentration over a 40-hour work week. OSHA recognizes, however, that work shifts can extend beyond the regular eight-hour period as the result of overtime or other alterations of the work schedule. This extension of work time also extends the time during which the employee is exposed. The effects of this additional exposure time must be considered in arriving at a level of exposure.

For the purpose of calculating an exposure level, the relationship of concentration and time of exposure has been assumed to be linear. As the time increases, the factor of concentration multiplied by time ($C \times T$) should remain constant. Thus, for example, employees exposed to SO_2 for ten hours could not be exposed to more than 1.6 ppm on the average. It is believed that by equating exposure with the eight-hour TWA, reasonable assurance of maintaining a safe level is retained.

D. *Dermal exposure limit.*—Liquid sulfur dioxide from pressurized containers can produce severe corneal burns upon contact with the eyes, resulting in opacification and loss of vision. The pressurized liquid is also irritating to the skin and may freeze and burn the skin due to its rapid evaporation.

For these reasons, the proposed standard would prohibit employers from exposing employees to any eye or skin contact with liquid sulfur dioxide.

E. *Determination and measurement of exposure.*—Each employer is required to make an initial determination of employee exposure to airborne or liquid sulfur dioxide. This initial determination may be an observation based on the amount of sulfur dioxide present, type of operations being performed, the amount of ventilation, and the proximity of employees to the sources of emission. Also, the employer must consider any employee complaints of symptoms that may be attributable to sulfur dioxide exposures. No measurements of employee exposure are required at this time. However, if the employer has made any measurements, these must also be considered in the determination. This determination must reflect employee conditions over the entire work day, as well as ceiling excursions.

In establishments having more than one work operation involving the use of sulfur dioxide, an initial determination must be made for each operation. Also, the determination must be repeated each time there is a change in production, process, or control measures which could result in new or additional exposure conditions.

If the results of the initial determinations are negative, that is, if the employer determines that no employee is exposed to potential skin or eye contact with sulfur dioxide, or to concentrations of sulfur dioxide at or above the action level or above the ceiling limit, a written record of this determination must be made. This record must contain any information or observations that indicate an employee may be exposed in any of the ways mentioned, including employee complaints of symptoms that may be attributable to overexposure. Further, the determination record must include any measurements of sulfur dioxide that have been made (although none are required to be made at this time), and the names and social security numbers of the employees considered under the determination. When results of the initial determination of dermal exposure indicate that any employee may be exposed by skin or eye contact to liquid sulfur dioxide, the employer must provide affected employees with protective clothing and devices to protect the area(s) of the body likely to come in contact with sulfur dioxide.

If the results of the initial determination of inhalation exposure are positive, indicating that an employee may be exposed to concentrations of the gas at or above the action level, or in excess of the ceiling limit, the employer would be required to measure the exposure of the employee believed to have the greatest exposure. Because a positive determination indicates possible exposure in excess of either the action level or ceiling limit, thus triggering the exposure measurement program, with its own recordkeeping requirements, no written records of positive determinations need be made.

When the results of the single employee's exposure measurement reveal exposures in excess of the action level or the ceiling limit, the employer would be required to identify all other employees who might be similarly exposed, and to measure the exposures of each of these employees. The proposed standard contains detailed instructions for monitoring the exposure of such employees.

The measurement procedures may be terminated if the measured employee's exposure does not indicate exposures in excess of the action level or ceiling limit. However, it should be noted that if an employer has knowledge of a production, process, or control change which could result in increased exposure to sulfur dioxide, or if the employer has any other reason to suspect that a change in exposure conditions has occurred, the determination procedure must be repeated.

The monitoring provisions are designed so that employers need not perform regular periodic measurements with respect to operations or workplaces in which sulfur dioxide exposures are below the action level (without regard to the use of respirators). Further, those employers having establishments with exposures at or above the action level, but below the TWA, would be required to make only the minimum number of exposure measurements necessary to assure that employees' exposures remained within those limits. The intent of these procedures is to provide adequate protection for employees while minimizing the burden on employers.

F. *Methods of measurement.*—The proposal would require that exposure measurements reflect the actual exposure conditions for each employee. It is recommended that a personal breathing zone sampling method that gives an accurate indication of the employee's exposure be used (See Appendix D). Further, any appropriate combination of long-term or short-term samples would be acceptable. However, the proposal requires that all exposures be calculated on an 8-hour time-weighted average basis, with the exception of the ceiling concentration measurements.

For sulfur dioxide, the required analytical accuracy is 25 percent at a 95 percent confidence level. This means that out of a long series of measurements, 95 percent must be within 25 percent of the true value.

G. *Methods of compliance.*—The proposed standard would require the employer to immediately institute engineering controls to reduce employee exposures to or below the 2 ppm TWA and the 10 ppm ceiling, except in situations in which such controls are infeasible. Further, in areas where engineering controls that can be instituted immediately will not reduce exposures to the permissible exposure limits, they must nonetheless be used to reduce exposures to the lowest practicable level, and be supplemented by the use of work practices.

Where engineering controls and work practices will not reduce exposures to the permissible exposure limits, they must nonetheless be implemented to reduce exposures to the lowest practicable limit, and be supplemented by the use of personal protective devices, such as respirators. In addition, a program must be established and implemented to reduce exposures to within the permissible exposure limits, or to the greatest extent feasible, solely by means of engineering controls. These plans must be reviewed and updated regularly to reflect the current status of exposure control.

Engineering controls are the preferred means of compliance because they reduce exposure hazards in the workplace environment by removing the airborne contaminant. Engineering controls may include the installation of local exhaust ventilation or the modification of a process so as to reduce emission of the contaminant into the workplace. When mechanical ventilation is used for engineering control, checks of air system efficiency, such as capture velocity, duct velocity, or static pressure must be made at least every three months. These checks are necessary to assure that the primary control system (mechanical ventilation) is functioning effectively at all times.

When engineering controls prove to be infeasible or inadequate, work practices become the preferred means of compliance. Work practice controls include such items as good housekeeping and adherence to proper process techniques. However, work practice controls are effective only when strong supervisory control is maintained, and are therefore less reliable than engineering controls.

Respirators are the least satisfactory means of control because of certain difficulties inherent in their use. Respirators are capable of providing good protection

only if they are properly selected for the concentrations of airborne contaminants present, properly fitted to the employee, worn by the employee, and replaced when they have ceased to provide protection. While it is possible for all of these conditions to be met, it is often the case that they are not, and as a consequence, the protection of employees by respirators is not as effective as the protection provided by engineering and work practice controls.

H. *Medical surveillance.*—The proposed standard contains medical surveillance requirements for employers having employees exposed at or above the action level. The purpose of the requirements is to ensure, to the extent possible, that early symptoms of overexposure or conditions which may be further aggravated by sulfur dioxide exposures are properly diagnosed and appropriate measures taken.

As discussed in section II of this notice, the toxic effects of sulfur dioxide stem from its irritant properties. Since most of the toxic effects involve the respiratory mechanism, it is necessary to perform chest x-rays and pulmonary function tests, as well as a general physical examination on employees who are, or will be, exposed to sulfur dioxide. Skin and eye examinations are also required in the proposal to identify those persons with conditions that may be worsened by the irritant effects associated with sulfur dioxide exposures.

Although the proposal specifies the types of medical tests and examinations to be given employees, the employer may allow the examining physician to use other types of medical examinations, provided they can give at least equal assurance of detecting the medical conditions pertinent to protecting employees against sulfur dioxide exposure. If the examining physician elects to use such alternative medical examinations, the employer must obtain a statement from the physician setting forth the alternative medical examinations and the rationale for their substitution. Further, the employer must inform the affected employees that medical examinations other than those prescribed by the standard are to be made available.

The employer must provide the examining physician with a copy of the standard for sulfur dioxide, including appendices; a description of the employee's duties; a description of any personal protective equipment used by the employee; the results of the employee's exposure measurement; and an estimate of the levels to which the employee will be exposed. The employer must also provide any available employee medical history information requested by the physician.

Following the medical examination, the employer must obtain a written opinion from the examining physician stating whether the employee has any medical condition that would be aggravated by exposure to sulfur dioxide. Additionally, the physician's opinion must state any recommended limitations upon the employee's exposure or upon the employee's use of protective equipment and respirators. Also, the opinion must state that the employee has been informed of any medical conditions which require further examination or treatment, although the written opinion must not contain specific findings or diagnoses unrelated to the employee's exposure to sulfur dioxide. The employer must provide a copy of the physician's written opinion to the employee.

If, based on the physician's opinion, the employer determines that exposure of an employee to sulfur dioxide would materially impair the employee's health, the employer must place specific limitations on the employee's continued exposure to sulfur dioxide so as to remove the employee from increased risk.

If an employee refuses to take an examination, the proposed standard contains a provision requiring the employer to inform the employee of the risks that may be incurred as a result of his refusal, and to obtain a signed statement from the employee stating that the employee fully understands the potential risks, but still does not wish to be examined. The purpose of this provision is not to encourage employees to avoid medical examinations. On the contrary, OSHA believes the positive action taken by employers to inform employees of the risks involved will encourage employees to undergo the examinations.

I. *Employee information and training.*—Information and training are essential for the protection of employees because an employee can do much to protect himself if, and only if, he is informed of the nature of the hazards in his workplace. To be effective, an employee education system must apprise the employee of the specific hazards associated with his work environment. For this reason, the employer must inform each employee, in detail, about the nature of the sulfur dioxide-related health problems, the necessity for exposure control, and the medical and industrial hygiene monitoring programs. Further, the employee must be instructed to report promptly the development of symptoms or conditions which could be attributed to overexposure to sulfur dioxide.

The proposed standard would require the employer to take positive action in informing his employees about the hazards of sulfur dioxide. The proposal would also require the employer to present the information contained in the substance safety data sheet and substance technical guidelines (Appendixes A and B), to inform the employees of the purpose for, proper use of, and limitations of respiratory protection devices, and to explain procedures to be followed in emergencies. Additionally, the training program must include a review of this standard.

J. *Recordkeeping.*—The proposed standard would require employers to keep written records of the following: initial determinations which indicate that employees are not exposed at or above the action level or above the ceiling limit; measurements of employee exposure; tests of mechanical ventilation system efficiency (where such systems are used for engineering control); annual training and information sessions; medical examinations; and pre-placement histories.

Besides showing that an employer has made an examination of the workplace, records of negative determinations also assist the employer in pinpointing areas of his operations where there might be potential for exposure above the action level in the future. Records of initial positive determinations, however, are not needed, because a positive determination requires the employer to take other actions which carry their own recording requirements.

When symptoms of organic damage appear, a physician often needs information as to the patient's previous medical conditions to make an accurate diagnosis of the problem and its apparent cause. Records of previous occupational medical examinations could be an invaluable aid to the physician treating a patient with organic damage which may be due to exposure to a toxic chemical substance. For this reason, the proposal would require the employer to retain records of employee exposure measurements and medical examinations for the duration of employment plus 5 years, even if the employee ceases to work for the employer.

A record of the tests of mechanical ventilation system efficiency is required to be maintained so that the employer can ensure that tests of the system are being made at the required time intervals. Further, the record is useful to the employer, since comparison of the most recent test with previous tests will assist in the evaluation of the effectiveness of the ventilation system, and will enable the employer to detect any progressive loss of efficiency before it becomes critical.

Section 8(c)(3) of the Act requires, and paragraph (k) of this proposal contains provisions for, access to records of exposure measurements by employees and former employees or their representatives, and for access to medical records made pursuant to paragraph (h) by physician designated by employees or former employees. It should be noted that such access is limited to the records of determinations, exposure measurements, and medical examinations that are being maintained by the employer in accordance with the recordkeeping requirements. It should also be noted that the employer is not required to retain or make those records accessible for periods longer than those required in paragraph (k) of the proposed standard.

The proposal provides for the transfer of monitoring and medical records, when: (1) one employer succeeds another, or (2) an employer ceases to do business and there is no successor. An employer succeeding another is required to receive and maintain those records which his predecessor would have been required to keep. Employers closing out their businesses without successors are required to send their records to NIOSH and notify each employee and former employee of the transfer.

OSHA is aware that certain provisions of this proposal, such as medical surveillance and the extended retention period for medical monitoring records may pose special problems to some employers, especially those who have small numbers of employees, operate with nonfixed places of employment, or use workforces which are highly transient in nature.

This awareness has been expressed by the Department of Labor in a statement submitted to the House Subcommittee on Environmental Problems Affecting Small Business on 26 June 1975, as follows: "It has become increasingly evident that the combined body of Federal regulations imposes a substantial, and, to some extent, unnecessary burden upon employers, particularly those who run small businesses. While most of these requirements serve a necessary and useful purpose, a definite potential exists for duplication, conflicting standards, and inappropriate recordkeeping requirements. In an effort to eliminate problems where any exist in the Department of Labor, I have requested my agency heads to assess the small business impact of the laws they administer and determine what can be done to ease the burden on the small employer, while still assuring compliance with the law."

Although it is clear that OSHA's first and prime responsibility is to assure employees safe and healthful places of employment, the Act and its legislative history recognize that economic and technological feasibility are legitimate factors to be considered in the setting of occupational safety and health standards.

In addition, the Act explicitly takes cognizance of its impact upon affected small business, specifically with respect to any recordkeeping requirements which are imposed.

Pursuant to section 8(d) of the Act, OSHA is exploring methods of reducing, to the maximum extent possible, the administrative and economic burdens of the proposal's various recordkeeping requirements.

While the proposal does not address itself to specific alternatives, OSHA invites comments concerning options which would both provide full protection to affected employees and at the same time minimize the administrative and economic burden on affected employers—especially those with small numbers of employees, non-fixed workplaces, or highly transient workforces.

(K) *Observation of monitoring.*—Section 8(c)(3) of the Act requires employers to provide employees or their representatives with the opportunity to observe monitoring of employee exposures to toxic materials or harmful physical agents. In accordance with this section, the proposed standard contains provisions for such observation. To ensure that the right to observe is meaningful, observers would be entitled to receive an explanation of the measurement procedure, and to record the results obtained.

It should be noted that the observer, whether an employee or designated representative, must be provided with and is required to use any personal protective devices required to be worn by employees working in the area that is being monitored, and must comply with all other applicable safety procedures.

(L) *Appendices.*—Four appendices have been included in this proposal: Appendix A, "Substance Safety Data Sheet;" Appendix B, "Substance Technical Guidelines;" Appendix C, "Medical Surveillance Guidelines"; and Appendix D, "Methods for Sampling and Analytical Procedures for Determination of Sulfur Dioxide." It should be noted that the appendixes have been included for informational purposes. None of the statements contained therein should be construed as a mandatory regulation, unless the same statement appears in the proposed standard.

The information contained in Appendices A and B is meant to aid the employer in complying with requirements of the standard. This information is also to be provided to employees as part of the annual training and education program.

Appendix C gives the employer a means of providing the examining physician with an explanation of the potential health effects of sulfur dioxide exposure and information needed by the physician to make an accurate interpretation of other types of examinations, not required by the standard, which may help the physician in making an accurate assessment as to whether any limitation should be placed upon the employee's exposure to SO_2.

Appendix D suggests a method of sampling and analytical procedures for determination of SO_2.

V. Conclusion

The Secretary recognizes that many of the matters considered in this proposal are controversial and that gaps exist in the available scientific evidence, especially in the area of the chronic effects due to SO_2 exposure. Unanswered questions cannot be permitted to hold back the process of setting a standard for protecting workers exposed to SO_2. The Secretary believes that over-exposure to sulfur dioxide is undesirable. Considering the best available evidence at present, OSHA has determined permissible exposure limits below which there is little likelihood of finding deleterious effects of SO_2 exposure among workers.

Therefore, based on the available evidence and in view of the above consideration, we believe that employee exposures to SO_2 must be reduced to the level of 2 ppm for an 8-hour TWA based on a 40-hour work week and be accompanied by a ceiling limit of 10 ppm based on a sampling period of 15 minutes, as set forth in the proposal. We further believe that on the basis of the available information, it will be feasible to reduce employee exposure to the permissible exposure.

VI. Environmental Impact Assessment

The National Environmental Policy Act of 1969 (NEPA) (42 U.S.C. 4321–4347), requires, among other things, that Federal agencies assess their proposed major actions, including rulemaking, to determine whether a significant impact on the quality of the human environment may result. Furthermore, 29 CFR 1999.3(d) requires that where OSHA determines that an environmental impact statement should be prepared, the determination to do so must be published in the Federal Register. Accordingly, it is hereby noticed that OSHA intends to prepare an environmental impact statement on the proposed standard for occupational exposure to sulfur dioxide in accordance with the requirements of 29 CFR Part 1999.

Once the draft environmental impact statement has been prepared, a copy of it will be made available by OSHA to any member of the public who requests an opportunity to comment on it. Any person or agency submitting comments on it to OSHA must at the same time forward five copies of the comments to the Council on Environmental Quality (CEQ), 722 Jackson Place, NW., Washington, D.C. A 45-day period will be allowed for the submission of comments after the publication of the notice of availability of the draft environmental impact statement. The draft statement will be available, where practicable, at least 15 days prior to a public hearing on the proposed standard. The environmental impact of the proposal would be an appropriate issue at such hearing.

It appears at present that the preceding preamble to the proposed standard for occupational exposure to sulfur dioxide adequately assesses the impact of the proposal on the workplace environment. It further appears that the proposed standard for occupational exposure to sulfur dioxide will have no significant effects on the quality of the human environment external to the workplace. The proposal does not increase the amount of sulfur dioxide released into the ambient air, nor does the proposal call for changes of industry practice in disposal of sulfur dioxide wastes. For these reasons, OSHA does not anticipate any increased impact on the community contiguous to establishments in which sulfur dioxide is used or produced.

Interested persons may submit comments that may be helpful in preparing the draft environmental impact statement on the proposed standard. Any person having relevant information or data not readily available in the open literature is invited to submit it to David R. Bell, Office of Standards Development, Occupational Safety and Health Administration, U.S. Department of Labor, 200 Constitution Avenue, N.W., Room N3669, Washington, D.C. 20210, by December 24, 1975. Comments submitted in regard to the proposed standard need not be resubmitted. All material received on environmental impact will be available for public inspection and copying at the above address.

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VIII. Public Participation

Interested persons are invited to comment on the proposed standard on or before January 23, 1976. Written data, views, and arguments concerning the proposal must be submitted in quadruplicate to the Docket Officer, Docket No. H–039, Room N–3620, 200 Constitution Avenue, N.W., Washington, D.C. 20210 (Telephone 202/523–8076). Written submissions must clearly identify the provision of the proposal addressed and the position taken with respect to each such provision. The data, views, and arguments will be available for public inspection and copying at the above address. All written submissions received will be made a part of the record of this proceeding.

Pursuant to 29 CFR 1911.11 (b) and (c), interested persons may, in addition to filing written comments as provided above, file objections to the proposal and request an informal hearing with respect thereto, in accordance with the following conditions:

1. The objections must include the name and address of the objector;

2. The objections must be postmarked on or before January 23, 1976;

3. The objections must specify with particularity the provision of the proposed rule to which objection is taken, and must state the grounds therefor;

4. Each objection must be separately stated and numbered; and

5. The objections must be accompanied by a detailed summary of the evidence proposed to be adduced at the requested hearing.

In addition to the comments and objections invited above, concerning the proposal and its environmental impact, OSHA hereby solicits comments from interested parties regarding the potential inflationary impact of the proposed standard. Comments must be submitted in accordance with the above requirements for comments on the proposal and may be directed toward any or all of the following subjects:

1. Cost impact on consumers, businesses and markets, or Federal, State, or local governments;

2. Effect on the productivity of wage earners, businesses, or government;

3. Effect on competition;

4. Effect on supplies of important materials, products, or services;

5. Effect on employment; and

6. Effect on energy supply or demand.

It is OSHA's intention to prepare an inflationary impact statement and analysis, if appropriate, or a certification that the standard has no substantial inflationary impact, and to make such statement or certification available at least 30 days prior to any public hearings on the proposed standard. The potential inflationary impact of the proposed standard. The potential inflationary impact of the proposed standard would be an appropriate issue at such hearings.

This procedure has been concurred in by the Council on Wage and Price Stability in accordance with the Office of Management and Budget Circular A–107 (January 28, 1975), issued pursuant to Executive Order 11821 (39 FR 41501, November 27, 1974).

Accordingly, pursuant to sections 4(b), 6(b) and 8(c) of the Occupational Safety and Health Act of 1970 (84 Stat. 1592, 1593, 1599; 29 U.S.C. 653, 655, 657) and 29 CFR Part 1911, it is hereby proposed to amend Part 1910 of Title 29 of the Code of Federal Regulations as set forth below.

Signed in Washington, D.C., this 14th day of November 1975.

John T. Dunlop,
Secretary of Labor.

1. Table Z–1 in 29 CFR 1910.1000 is proposed to be amended by deleting the following:

*	*	*	*	*
Sulfur dioxide		5 (p/m)		13 (mg/m³)
*	*	*	*	*

2. A new § 1910.1030 is proposed to be added to Part 1910 of Title 29 of the Code of Federal Regulations, reading as follows:

§ 1910.1030 Sulfur dioxide.

(a) *Scope and application.* This section applies to the production, release, storage, handling, transportation, or use

of sulfur dioxide except as to working conditions with respect to which any other Federal agency has exercised statutory authority to prescribe or enforce standards or regulations affecting occupational safety or health hazards covered by this section.

(b) *Definitions.* "Action level" means a concentration of sulfur dioxide greater than or equal to 1 ppm (2.61 mg/m³) determined on an 8-hour time-weighted average based on a 40 hour work week, at or above which certain actions prescribed by this standard must be initiated.

"Director" means the Director, National Institute for Occupational Safety and Health, U.S. Department of Health, Education, and Welfare, or his designee.

"Emergency" means any occurrence such as, but not limited to equipment failure, rupture of containers, or failure of control equipment which is likely to, or does, result in an unexpected release of sulfur dioxide.

"Secretary" means the Secretary of Labor, U.S. Department of Labor, or his designee.

"Sulfur dioxide" means sulfur dioxide in the form of gas or pressurized liquid.

(c) *Permissible exposure limits.* (1) *Inhalation exposure limits.* (i) *Time-weighted average limit (TWA).* No employee may be exposed to an 8-hour time-weighted average concentration based on a 40 hour work week of sulfur dioxide in excess of 2 ppm (5.23 mg/m³).

(ii) *Ceiling limit.* No employee may be exposed to an airborne concentration of sulfur dioxide in excess of 10 ppm (26.12 mg/m³) as determined by a sampling time of 15 minutes.

(2) *Dermal exposure.* No employee may be exposed to skin or eye contact with liquid sulfur dioxide.

(d) *Determination and measurement of exposure.* (1) *Determination of requirement for measurement.* Each employer who has a place of employment in which sulfur dioxide is present, shall inspect each workplace and work operation to determine if any employee may be exposed, without regard to the use of respirators, to airborne concentrations of sulfur dioxide at or above the action level or in excess of the ceiling limit, or to skin or eye contact with liquid sulfur dioxide. Such a determination shall be based on the following, along with any other relevant considerations:

(i) Any information, observations, or calculations which would indicate employee exposure to sulfur dioxide;

(ii) Any measurements of airborne sulfur dioxide; and

(iii) Any employee complaints of symptoms which may be attributable to exposure to sulful dioxide.

(2) *Negative determination.* When a determination is made that no employee is exposed to airborne concentrations of sulfur dioxide at or above the action level or in excess of the ceiling limit or by skin or eye contact with liquid sulfur dioxide, the employer shall make a record of such determination. This record shall include any records of measurements of sulfur dioxide level, any information which would indicate employee exposure, employee complaints of symptoms which may be attributable to exposure to sulfur dioxide, the date of the determination, work being performed at the time, the location within the work site, and the names and social security numbers of employees considered.

(3) *Positive determination.* When a determination conducted under paragraph (d)(1) of this section indicates the possibility of any employee exposure at or above the action level or in excess of the ceiling limit, without regard to the use of respirators, the employer shall within 30 days, measure the exposure of the employee believed to have the greatest exposure in each work operation in which a positive determination is made. The exposure measurement shall be representative of the maximum exposure to the employee.

(4) *Exposed employee identification.* If the exposure measurement taken pursuant to paragraph (d)(3) of this section reveals employee exposure to airborne concentrations of sulfur dioxide to be at or in excess of the action level or in excess of the ceiling limit, the employer shall:

(i) Identify all employees who may be similarly exposed; and

(ii) Measure the exposures of the employees so identified.

(5) *Exposure between action level and TWA.* If exposure measurements reveal employee exposure at or above the action level, but below the TWA and ceiling limit, the employer shall repeat measurements for such employees at least every two months.

(6) *Exposure over TWA or ceiling limit.* If exposure measurements reveal employee exposure to be above the TWA or ceiling limit, the employer shall:

(i) Inform the employee in writing of the exposure as required by paragraph (d)(11) of this section;

(ii) Measure the exposure of the employee at least monthly; and

(iii) Institute control measures as required by paragraph (e) of this section.

(7) *Remeasurements below action level.* If two consecutive measurements, taken at least one week apart, reveal that an employee is exposed to concentrations of sulfur dioxide below the action level and the ceiling limit, the employer may discontinue exposure measurement for that employee.

(8) *Records.* A record of all measurements shall be made and shall include at least the information required in paragraph (d)(2) of this section.

(9) *Liquid sulfur dioxide contact.* Where a determination conducted under paragraph (d)(1) of this section shows the possibility of employee exposure by skin or eye contact with liquid sulfur dioxide, the employer shall provide such employees with protective devices and clothing in accordance with paragraph (g) of this section.

(10) *Redetermination.* Whenever there has been a production, process, or control change which may result in new or additional exposures, or whenever the employer has any other reason to suspect a change in exposure conditions, a new determination under paragraph (d)(1) of this section shall be made.

(11) *Employee notification.* The employer shall individually notify in writing, within 5 working days after receipt of measurement results, every employee who is found to be exposed to sulfur dioxide above the TWA or ceiling limit. The employee shall also be notified of the corrective action being taken to reduce exposure to within permissible limits.

(12) *Accuracy of measurement.* The method of measurement shall have an accuracy (within a confidence limit of 95%) of not less than plus or minus 25% for concentrations of sulfur dioxide greater than or equal to 1.0 ppm.

(e) *Methods of compliance.* Employee exposures to sulfur dioxide shall be controlled to or below the TWA and ceiling limit provided in paragraph (c) of this section by engineering controls, work practices, and personal protection controls as follows:

(1) *Control priorities.* (i) Engineering controls shall be instituted immediately to reduce exposures to or below the TWA and the ceiling limit except to the extent that such controls are not feasible.

(ii) Wherever engineering controls which can be instituted immediately are not sufficient to reduce exposure below the TWA and ceiling limit, they shall nonetheless be used to reduce exposures to the lowest practicable level and shall be supplemented by work practice controls.

(iii) Where engineering and supplemental work practice controls are not sufficient to reduce exposures to or below the TWA and ceiling limit, they shall nonetheless be used to reduce exposures to the lowest practicable level, and shall be supplemented by the use of respiratory protection in accordance with paragraph (e)(4) of this section.

(2) *Compliance program.* (i) A program shall be established and implemented to reduce exposures to or below the TWA and the ceiling limit or to the greatest extent feasible, solely by means of engineering controls.

(ii) Written plans for such a program shall be developed and furnished upon request for examination and copying to the Secretary and the Director. Such plans shall be reviewed and revised at least every six months to reflect the current status of the program.

(3) *Mechanical ventilation.* When mechanical ventilation is used to control exposure, measurements which demonstrate the effectiveness of the system to control the exposure, such as capture velocity, duct velocity, or static pressure, shall be made at least every three months. Measurements of the system's effectiveness to control exposure shall also be made within five days of any change in production, process or control which might result in any change in airborne concentrations of sulfur dioxide.

(4) *Respiratory protection.* (i) *Required use.* Compliance with the permissible exposure limits may not be achieved by the use of respirators except:

(a) During the time period necessary to install engineering controls or work practice controls or both;

(b) In work operations in which engineering controls and supplemental work practice controls are not feasible;

(c) In work situations in which feasible engineering controls and supplemental work practice controls are insufficient to reduce exposure to or below the TWA and the ceiling limit; or

(d) In emergencies.

(ii) *Respirator selection.* (a) Where respiratory protection equipment is to be used in accordance with paragraph (e)(4)(i) of this section, the employer shall select and provide the appropriate respirator from the table below, and shall ensure that the affected employee uses the respirator provided.

(b) The appropriate respirator in accordance with the table below must be worn at any time the permissible exposure limit is exceeded.

REQUIREMENTS FOR RESPIRATOR USAGE

Concentration of SO_2	*Permissible respirator protection*
Less than or equal to 50 p/m.	Chemical cartridge respirator for sulfur dioxide with quarter, half, or full facepiece (30 CFR 11.150). Type C supplied-air respirator, demand type (negative pressure) with quarter or half mask facepiece (30 CFR 11.110).
Less than or equal to 500 p/m.	Gas mask with chin-style canister for acid gases (30 CFR 11.90(a)(3)). Gas mask with front- or back-mounted chest-type canister for acid gases (30 CFR 11.90(a)(1)). Type C supplied-air respirator, demand (negative pressure); pressure-demand; or continuous flow type with full facepiece (30 CFR 11.110). Self-contained breathing apparatus in demand mode (negative pressure) with full facepiece (30 CFR 11.70(a)(2)(i)).
Greater than 500 p/m and emergency.	Self-contained breathing apparatus in pressure-demand mode (positive pressure) (30 CFR 11.70(a)(2)(ii)).

(c) Respirators shall be selected from those approved by the Mining Enforcement and Safety Administration (formerly called the Bureau of Mines) or by the National Institute for Occupational Safety and Health under the provisions of 30 CFR Part 11.

(d) Respirators prescribed for higher concentrations may be used for any lower concentration.

(iii) *Respirator program.* (a) The employer shall institute a respiratory protection program in accordance with § 1910.134.

(b) Employees who wear respirators shall be allowed to leave work areas to wash the face and respirator facepiece to prevent potential skin irritation associated with respirator use.

(f) *Emergency situations.* (1) *Written plan.* (i) A written plan for emergency situations shall be developed for each facility involved in a sulfur dioxide operation in which there is a possibility of an emergency as defined in paragraph (b) of this section. Appropriate portions of the plan shall be implemented in the event of an emergency.

(ii) The plan shall specifically provide that employees engaged in correcting emergency conditions shall be equipped with respirators and protective clothing in accordance with paragraphs (e)(4) and (g) of this section until the emergency is abated.

(iii) Employees not engaged in correcting the emergency shall be restricted from the area and normal operations in the affected area shall not be resumed until the emergency is abated.

(2) *Alerting employees.* Where there is the possibility of employee exposure to sulfur dioxide in excess of the ceiling level due to the occurrence of an emergency, a general alarm shall be installed and maintained to promptly alert employees of such occurrences.

(g) *Personal protective equipment.* (1) *Skin contact.* Employers shall provide, and ensure that employees wear, impervious clothing, gloves, face shields (8 inch minimum), and other appropriate protective clothing as necessary to prevent skin contact with liquid sulfur dioxide. Face shields shall comply with § 1910.133(a)(2)–(a)(6).

(2) *Eye contact.* Employers shall provide, and ensure that employees use cup-cover type dust and splash-proof safety goggles, which comply with § 1910.133(a)(2)–(a)(6), where liquid sulfur dioxide may contact the eyes.

(h) *Medical surveillance.* (1) *General requirements.* (i) Each employer who has a place of employment in which employees are or will be exposed to concentrations of sulfur dioxide at or above the action level or the ceiling limit, without regard to the use of respirators, shall institute a medical surveillance program.

(ii) The program shall provide each affected employee with an opportunity for medical examinations in accordance with this paragraph.

(iii) All medical examinations and procedures shall be performed by or under the supervision of a licensed physician, and shall be provided during the employee's normal working hours, without cost to the employee.

(iv) If any employee refuses any required medical examination, the employer shall inform the employee of the possible health consequences of such refusal and shall obtain a signed statement from the employee indicating that the employee understands the risk involved in the refusal to be examined.

(2) *Initial examinations.* At the time of initial assignment, or upon institution of medical surveillance, the following shall be performed by the physician.

(i) A work history and a medical history which are designed to determine whether the employee has experienced any respiratory symptoms, i.e., breathlessness, cough, sputum production, and wheezing; vision impairments or chronic skin disease; and

(ii) A medical examination which must include as a minimum the following:

(a) A 14 x 17 posterior-anterior chest x-ray;

(b) Pulmonary function tests to include Forced Vital Capacity (FVC) and Forced Expiratory Volume in one second (FEV_1);

(c) An eye examination; and

(d) A skin examination.

(3) *Periodic examinations.* Examinations specified in this paragraph shall be performed at least annually for all employees specified in paragraph (h)(1)(i) of this section.

(4) *Alternative medical examinations.* If in the judgement of the examining physician, medical examinations alternative to those specified in paragraph (h)(2) of this section will provide at least equal assurance of detecting medical conditions pertinent to protecting the employee against exposure to sulfur dioxide, the employer may accept such alternative medical surveillance examinations as meeting the requirements of this section, provided that the employer:

(i) Obtains a statement from the examining physician setting forth the alternative medical examinations and the rationale for their substitution;

(ii) Informs each exposed employee of the fact that medical examinations alternative to those required in paragraph (h)(2) of this section are to be made available.

(5) *Information provided to the physician.* The employer shall provide the following information to the examining physician.

(i) A copy of this regulation for sulfur dioxide including Appendices A, B, and C;

(ii) A description of the affected employee's duties as they relate to the exposure to sulfur dioxide;

(iii) The results of the employee's exposure measurement, if available;

(iv) A description of any personal protective equipment used;

(v) The employee's estimated exposure level; and

(vi) Upon request of the physician, information from previous medical examinations of the affected employee.

(6) *Physician's written opinion.* (i) The employer shall obtain a written opinion from the examining physician, containing the following:

(a) The physician's opinion as to whether the employee is at increased risk of material impairment of the employee's health from exposure to sulfur dioxide or whether the exposure would directly or indirectly aggravate any medical condition;

(b) Any recommended limitations upon the employee's exposure to sulfur dioxide and upon the use of protective equipment and respirators; and

(c) A statement that the employee has been informed by the physician of any medical conditions which require further examination or treatment.

(ii) The written opinion shall not reveal specific findings or diagnoses unrelated to exposure to sulfur dioxide.

(iii) A copy of the written opinion shall be provided to the affected employee.

(iv) If the employer determines, on the basis of the physician's written opinion, that any employee's health would be materially impaired by continued exposure to sulfur dioxide, the employer shall place specific limitations, based on the physician's written opinion, on the employee's continued exposure to sulfur dioxide. In no case shall any employee be placed at increased risk of material impairment of health from such exposure.

(i) *Employee information and training.* (1) *Training program.* (i) The employer shall provide a training program for employees assigned to workplace areas in which any sulfur dioxide is produced, released, stored, handled, or used.

(ii) The training program shall be provided at the time of initial assignment, and at least annually thereafter, and shall include informing each employee of:

(*a*) The information contained in the substance data sheets for sulfur dioxide, which are contained in Appendices A and B;

(*b*) The quantity, location, manner of use, release, or storage of sulfur dioxide and the specific nature of operations which could result in exposure at or above the action level, as well as any necesary protective steps;

(*c*) The purpose for, and a description of, the medical surveillance program as required by paragraph (h) of this section and the information contained in Appendix C;

(*d*) The purpose, proper use, and limitations of respiratory protection devices as specified in § 1910.134;

(*e*) Emergency procedures as required by paragraph (f) of this section; and

(*f*) A review of this standard.

(2) *Access to training materials.* (i) A copy of this standard and its appendices shall be made readily available to all employees who might be exposed to sulfur dioxide.

(ii) All materials relating to the employee information and training program shall be provided upon request to the Secretary and the Director.

(j) *Signs and labels.* (1) *General.* (i) Signs or labels required by this paragraph may be in addition to or in combination with signs or labels required by other statutes, regulations, or ordinances.

(ii) No statement shall appear on or near any required sign, label or instruction which contradicts or detracts from the effect of any such required sign, label or instruction.

(2) *Signs.* (i) All entrances or access ways to areas where sulfur dioxide is likely to be present to the extent that an employee may be exposed at or in excess of the action level, shall be marked with legible signs bearing at least the following information:

CAUTION (OR WARNING)
SULFUR DIOXIDE
IRRITANT GAS
AVOID INHALATION

(ii) The following sign shall be posted at all entrances or access ways to areas where concentrations of sulfur dioxide exceed the TWA or ceiling limit.

CAUTION (OR WARNING)

SULFUR DIOXIDE

IRRITANT GAS

USE RESPIRATORS IN THIS AREA

(3) *Labels.* Precautionary labels shall be applied to all containers, packages, or equipment containing sulfur dioxide. The label shall provide at least the following information:

(i) the word "CAUTION" or "WARNING";

(ii) The word "SULFUR DIOXIDE"; and

(iii) A statement concerning the irritant properties of sulfur dioxide and a warning to avoid inhalation or skin or eye contact.

(k) *Recordkeeping.* (1) *Exposure determinations.* The employer shall keep an accurate record of all determinations prescribed by paragraphs (d)(1), (d)(2) and (d)(11).

(i) This record shall include the written determinations and supporting documentation required by paragraphs (d)(1), (d)(2), and (d)(11) of this section.

(ii) This record shall be maintained for at least one year or until replaced by a more recent determination, whichever is longer.

(2) *Measurement.* The employer shall keep an accurate record of all measurements taken to monitor employee exposure to sulfur dioxide as prescribed by paragraphs (d)(3) to (d)(10) of this section.

(i) This record shall include:

(*a*) The date of measurement;

(*b*) The operation involving exposure to sulfur dioxide being monitored;

(*c*) The sampling and analytical methods used and their accuracy;

(*d*) Number, duration, and results of samples taken;

(*e*) Name, social security number, and exposure of the employees measured; and

(*f*) The type of respiratory protective devices worn, if any.

(ii) This record shall be maintained for at least twenty years.

(3) *Mechanical ventilation measurements.* When mechanical ventilation is used as an engineering control, the employer shall maintain a record of the measurements demonstrating the effectiveness of such ventilation as required by paragraph (e)(3) of this section.

(i) This record shall include:

(*a*) Date of measurement;

(*b*) Type of measurement taken; and

(*c*) Result of measurement.

(ii) This record shall be maintained for at least one year.

(4) *Employee training.* The employer shall keep an accurate record of all employee training required by paragraph (i) of this section.

(i) This record shall include;

(*a*) Data of training;

(*b*) Name and social security number of employee(s) trained; and

(*c*) Content and scope of training provided.

(ii) This record shall be maintained for at least one year.

(5) *Medical surveillance.* The employer shall keep an accurate medical record for each employee subject to medical surveillance required by paragraph (h) of this section.

(i) This record shall include:

(*a*) Physician's written opinion;

(*b*) Any employee medical complaints related to exposure to sulfur dioxide; and

(*c*) A copy of the information provided to the physician as required by paragraph (h)(5) of this section.

(ii) This record shall be maintained for the duration of employment of the affected employee plus five years.

(l) *Observation of monitoring.* (1) *Employee observation.* The employer shall give affected employees or their representatives an opportunity to observe any measuring of their exposure to sulfur dioxide which is conducted pursuant to this section.

(2) *Observation procedures.* (i) When observation of the monitoring of employee exposure to sulfur dioxide requires entry into an area where the use of personal protective devices is required, the observer shall be provided with and required to use such equipment and shall comply with all other applicable safety and health procedures.

(ii) Without interfering with the measurement, observers shall be entitled to:

(*a*) Receive an explanation of the measurement procedures;

(*b*) Observe all steps related to the measurement of airborne concentrations of sulfur dioxide performed at the place of exposure; and

(*c*) Record the results obtained.

(m) *Effective date.* This standard shall become effective 30 days following publication of the final standard in the FEDERAL REGISTER.

(n) *Startup dates.* (1) *Determination and measurement.* Determinations and measurements prescribed in paragraph (d) of this section shall be instituted within three months of the effective date of the final standard, except that for new production areas or operations, determinations and measurements shall be instituted within 30 days of startup of the new production areas or operations.

(2) *Medical surveillance.* Medical surveillance prescribed in paragraph (h) of this section shall be instituted within three months of the effective date of the final standard.

(o) *Appendices.* The information contained in the appendices to this section is advisory in nature and is not intended, by itself, to create any additional obli-

gations not otherwise imposed by the standard or to detract from any existing obligations.

APPENDIX A—SUBSTANCE SAFETY DATA SHEET—SULFUR DIOXIDE

I. SUBSTANCE IDENTIFICATION

A. *Substance:* Sulfur dioxide.

B. *Permissible exposure:* 1. *Airborne.* 2 ppm of sulfur dioxide (5.23 mg/m³), time-weighted average (TWA) for an 8-hour workday, with a ceiling limit of 10 ppm (26.12 mg/m³).

2. Dermal. No employee may be exposed to eye or skin contact with sulfur dioxide liquid.

C. *Appearance and Odor:* Sulfur dioxide has a strong pungent odor. Caution: The odor should not be used as a warning of its presence in the air, since it may deaden sense of smell.

II. HEALTH HAZARD DATA

A. *Comments:* Sulfur dioxide is an extremely irritating gas, or liquid.

B. *Ways in which sulfur dioxide affects your body:* Sulfur dioxide can affect your body if inhaled, or if it comes in contact with your skin, or if you swallow it.

C. *Effects of overexposure:*

1. *Acute.*

A. If you breathe excessive concentrations of sulfur dioxide, your eyes, nose, or throat will become irritated. Excessive concentrations may also cause upset stomach, vomiting, headache, sleepiness, dizziness, weakness, and incoordination. In extreme cases, sulfur dioxide may cause unconsciousness and asphyxiation.

B. Skin contact with liquid sulfur dioxide can cause severe burns to the skin.

C. Eye contact with liquid sulfur dioxide may cause corneal burns closely resembling those produced by acids and alkalies.

2. *Chronic.*

Long term exposure may reduce your upper respiratory function, and if it is in the presence of a cancer causing agent, may promote cancer.

III. REPORTING SYMPTOMS

You should inform your employer if you develop any of the above symptoms and suspect that they may be caused by exposure to sulfur dioxide.

IV. EMERGENCY AND FIRST AID PROCEDURES

1. *Inhalation.* If you breathe in large amounts of sulfur dioxide or if you develop any of the symptoms listed in II above, leave the contaminated area and get to fresh air immediately. Call a physician as soon as possible. If an employee breathes in large amounts of sulfur dioxide and the employee's breathing has stopped, apply artificial resuscitation. Call a doctor immediately.

2. *Eye or face exposure.* If liquid sulfur dioxide (in any state) is splashed in your eyes, wash it out immediately with large amounts of water. Call a doctor as soon as possible.

3. *Skin exposure.* If liquid sulfur dioxide is spilled on your clothing or skin, remove the contaminated clothing and wash the exposed skin immediately with large amounts of water, since skin contact can cause a sulfur dioxide burn.

4. *Swallowing.* If liquid sulfur dioxide is swallowed do not induce vomiting. In fact, dilution is necessary. Make victim drink water, or milk, and repeat dosage fluids. Call a physician immediately. Fifty percent of the persons who swallow sulfur dioxide die and 95 percent of the survivors receive permanent internal burns.

V. PROTECTIVE CLOTHING AND EQUIPMENT

Respirators: Suitable respirators are to be worn:

(1) During the time necessary to install engineering controls to reduce the airborne concentration of sulfur dioxide below 2 ppm;

(2) In work situations in which engineering controls are inadequate to reduce the airborne concentration of sulfur dioxide below the permissible exposure limits;

(3) In emergencies.

If respirators are worn, they must have a Mining Enforcement and Safety Administration or National Institute for Occupational Safety and Health approval label. Older respirators may have a Bureau of Mines approval label. If you can smell sulfur dioxide, the respirator is not working correctly. Go immediately to fresh air, then check the respirator for fitting and cartridge age. If you experience difficulty breathing while wearing a respirator, tell your employer.

VI. PRECAUTIONS FOR SAFE USE, HANDLING, AND STORAGE

Sulfur dioxide is nonflammable and a relatively stable gas. It should be stored in pressurized containers in well-ventilated areas, and at temperatures less than 165 degrees F. Cylinders and tank cars can be left in direct sunlight and appropriate temperatures. Cylinders and containers, however, should be stored away from heating ducts. Containers should be welded pressure tanks with the proper corrosive factor applied.

APPENDIX B—SUBSTANCE TECHNICAL GUIDELINES—SULFUR DIOXIDE

I. PHYSICAL AND CHEMICAL DATA

A. *Substance identification.*

1. Synonyms: Sulfurous Oxide, Sulfurous Anhydride

2. Formula: SO_2

B. *Physical data.*

1. Boiling Point (760 mm/hg): −10 C (14 F).

2. Specific Gravity (liquid): 1.434 at 0 C (32 F).

3. Vapor Density (air=1): 2.264.

4. Melting Point: −72.7 C (−99 F).

5. Vapor Pressure: @20 C (68 F): 3.2 atm.

6. Solubility in water @20 C (68 F): 11.28 g/100ccH2O.

C. *Appearance and odor:* Sulfur dioxide is a colorless gas which has a strong, pungent odor. Caution: The odor of this gas should not be used as a warning of its presence in air, since it may deaden the sense of smell. Sulfur dioxide can also exist as a liquid under low temperature and high pressure conditions.

II. FIRE, EXPLOSION AND REACTIVITY HAZARD DATA

A. *Fire:* 1. Sulfur dioxide gas and liquid is not flammable.

B. *Reactivity:* 1. Chemical stability: Sulfur dioxide is weakly reactive.

2. Incompatibility: Sulfur dioxide (gas) is not corrosive to ordinary metals; however, upon contact with moisture it does become corrosive.

3. Hazardous products: SO_2 (gas) on contact with moisture produces sulfurous acid.

III. SPILL, LEAK, AND DISPOSAL METHODS

Steps to be taken if the material is spilled or leaked:

1. No one should enter areas where sulfur dioxide has been released unless air testing shows concentrations are safe, and proper clothing, respirators, etc., are used. Respirators as prescribed by (e)(1)(iii) of the standard shall be used during emergencies, cleanup, and repair work.

2. Emergency procedures shall be followed for emergency entry into areas of high gas concentrations or liquid spills, until the situation has been resolved.

IV. MONITORING AND MEASUREMENT PROCEDURES

Measurements taken for the purpose of evaluating employee TWA exposure under this section are best taken in a fashion such that the average 8-hour exposure may be determined from continuous monitoring. Short time interval samples (up to 30 minutes) may also be used to determine average exposure level if a minimum of five (5) measurements are taken in a random manner over the 8-hour work shift. Random sampling means that any portion of the work shift has the same chance of being sampled as any other. The arithmetic average of 11 such random samples taken on one (1) work shift is an estimate of an employee's average level of exposure for that work shift. Air samples should be taken in the employee's breathing zone (air that would most nearly represent that inhaled by the employee). Sampling and analyses may be performed by instruments, such as detector tubes certified by NIOSH under 42 CFR Part 84, portable direct-reading instruments, or with continuous monitoring systems that can sample and analyze those areas most likely to represent the highest airborne concentrations of sulfur dioxide where employees are exposed. The analytical method must determine the concentrations of sulfur dioxide to plus or minus 25 percent.

V. MISCELLANEOUS PRECAUTIONS

A. Since sulfur dioxide vaporizes at ambient temperatures and pressure it should be stored in pressurized containers and kept at temperatures not to exceed 165 degrees F.

B. Fusible plugs: Never use a blow torch or flames to heat cylinders because plugs melt at 165 degrees F.

C. Employers shall advise employees of all plant areas and operations where exposure to sulfur dioxide could occur.

D. Since tanks are pressurized, unloading procedures should include proper depressurization.

VI. COMMON OPERATIONS

Occupations considered to frequently have exposures to sulfur dioxide are:

Beet sugar bleachers, blast furnace workers, brewery workers, diesel engine operators, diesel engine repairmen, disinfectant makers, disinfectors, firemen, flour bleachers, food bleachers, foundry workers, fruit bleachers, fumigators, fumigant makers, furnace operators, gelatin bleachers, glass makers, glue bleachers, ice makers, meat preservers, oil bleachers, oil processors, ore smelter workers, organic sulfonate makers, paper makers, petroleum refinery workers, preservative makers, protein makers, food protein makers, industrial refrigeration workers, straw bleachers, sugar refiners, sulfite makers, sulfur dioxide workers, sulfuric acid makers, sulfuryl chloride makers, tannery workers, textile bleachers, thermometer makers, vapor pressure, wicker ware bleachers, wine makers, wood bleachers, and wood pulp bleachers.

APPENDIX C—MEDICAL SURVEILLANCE SULFUR DIOXIDE

I. PHYSICAL AND CHEMICAL PROPERTIES

Sulfur dioxide, or SO_2, is chemically stable, noncombustible, and is widely present both as a manufactured substance and by-product. Sulfur dioxide can exist as a liquid under low temperature and high pressure conditions and has a strong, pungent odor.

II. ROUTE OF ENTRY

Primarily inhalation, insignificant skin absorption.

III. TOXICOLOGY

There is a great deal of irritation to the nose, throat, lungs, and eyes (effects may be more pronounced in unacclimated individuals).

IV. SYMPTOMS AND SIGNS

Acute irritation of the eyes (and possible blindness), of the mucous membranes, and of the upper respiratory tract, and headache. Excessive skin contact may produce a dermatitis; and at sustained levels asphyxia may result.

V. SPECIAL TESTS

Pulmonary function test, anterior and posterior x-rays.

VI. TREATMENT

Wash eyes and skin immediately. Give artificial resuscitation if indicated. Recovery is usually rapid and complete. If swallowed, do not make person vomit but dilute with water or milk.

VII. PREPLACEMENT

Routine medical histories and physical examination are required. The employer must screen prospective employees for history of certain medical conditions (listed below) which might place the employee at increased risk of exposure.

1. *Chronic respiratory disease:* In persons with impaired pulmonary function, especially those with obstructive airway disease, the breathing of sulfur dioxide might cause exacerbation of symptoms due to its irritant properties.

2. *Skin disease:* Liquid sulfur dioxide is a freeze-burn agent and does cause severe burns. Uticaria is common in some persons from exposure to the gas.

3. *Eye disease:* Liquid sulfur dioxide can be extremely damaging to the eyes especially the cornea. Therefore contact lenses should not be worn due to the freezing nature of the substance.

VIII. PERIODIC EXAMINATION

Routine periodic examinations are required. In addition, if an employer becomes aware of any of the listed conditions he must refer the employee for further medical examinations. It is important that the physician become familiar with plant operating conditions in which exposure to sulfur dioxide occurs. Prevention of overexposure consists of adequate local exhaust and general ventilation, protective clothing including gloves, respirators for emergencies, and washing contaminated skin and work areas.

APPENDIX D—RECOMMENDED METHOD FOR SAMPLING AND ANALYTICAL PROCEDURES FOR DETERMINATION OF SULFUR DIOXIDE

The following sampling and analytical method for analysis of sulfur dioxide in air employs absorption and oxidation in hydrogen peroxide solution followed by volumetric titration.

GENERAL REQUIREMENTS

Sulfur dioxide concentrations should be determined within the worker's personal breathing zone and should meet the following criteria in order to evaluate conformance with the standard:

(a) Samples collected must be representative of the individual worker's exposure.

(b) Sampling data sheets should include:

(1) The date and time of sample collection.

(2) Sample duration.

(3) Volumetric flowrate of sampling.

(4) A description of the sampling location.

(5) Other pertinent information.

A. *Personal breathing zone sampling*—1. Personal monitor samples.

A suggested method is that used by Smith, Wagner and Moore in their most recent study. In this study all samples were full-shift, 7 to 8 hours in duration. The personal exposure of smelter workers to airborne contaminants was measured with a particle-size selective device, designed to sample the breathing zone when the worker was not using his respirator. When the worker put on his respirator, his chin pressed a microswitch, which turned off the air pump and activated a timer that measured the cumulative time the respirator was worn.

(a) *Sampling equipment.* To replicate this method a calibrated personal sampling pump with flowmeter (range up to 2 liters/minutes), a midget impinger containing 15 ml of 0.3 N hydrogen peroxide absorbing solution, and an 0.8 micrometer nominal pore size cellulose membrane filter holder are used for sample collections.

(b) *Sampling procedure.* The filter is placed upstream of the impinger to collect any sulfuric acid mist or other airborne particulate sulfates prior to the air passing through the impinger. The filter holder is connected to the impinger inlet by a piece of flexible vinyl tubing as short as possible. The impinger outlet is connected to the personal sampling pump inlet by a piece of tubing of convenient length, but not in excess of 3 feet. The filter and impinger assembly is attached to the worker's clothing so as to sample from the worker's breathing zone. The sample is collected at a rate of 1–2 liters/minute for an appropriate length of time to attain a 100-liter air sample. If sulfur dioxide concentrations are expected to be greater than 100 mg/m³ of air (approximately 40 ppm), a smaller air volume should be sampled but never less than 10 liters.

A minimum of 3 samples is taken for each operation (more samples if the concentrations are close to the standard) and averaged on a timeweighted basis. At least one blank impinger is provided containing hydrogen peroxide solution through which no air has been sampled. One additional blank impinger is supplied with every 10 samples obtained.

SHIPPING

After sampling, one removes the glass stopper and impinger stem from the impinger bottle. The stem is tapped gently against the inside wall of the impinger bottle to recover as much of the sampling solution as possible. The stem is washed with a small amount of unused absorbing solution from a wash bottle, adding the wash to the impinger. The impinger is stopper tightly with plastic caps (do not seal with rubber), placed in an upright position, and shipped the impinger samples to the analytical laboratory in a suitable container to prevent damage in transit. Special impinger shipping containers designed by NIOSH are available. It is important that the impinger bottles be sealed very tightly to prevent leakage and subsequent loss of samples.

CALIBRATION OF SAMPLING TRAINS

Since the accuracy of an analysis can be no greater than the accuracy of the volume of air which is measured, the accurate calibration of a sampling pump is essential to the correct interpretation of the pump's indication. The frequency of calibration is dependent on the use, care, and handling to which the pump is subjected. In addition, pumps should be recalibrated if they have been misused or if they have just been repaired or received from a manufacturer. If the pump receives hard usage, more frequent calibration may be necessary.

Ordinarily, pumps should be calibrated in the laboratory both before they are used in the field and after they have been used to collect a large number of field samples. The accuracy of calibration is dependent on the type of instrument used as a reference. The choice of calibration instrument will depend largely upon where the calibration is to be performed. For laboratory testing, primary standards such as a spirometer or soapbubble meter are recommended, although other standard calibrating instruments such as a wet test meter or dry gas meter can be used. The actual setup will be the same for all instruments. Instructions for calibration with the soapbubble meter follow. If another calibration device is selected, equivalent procedures should be used.

(a) *Flowmeter calibration test method.* The calibration setup for personal sampling pumps with the sampling system of a filter and a midget impinger proceeds as follows:

(1) Procedure—

(A) Check the voltage of the pump battery with a voltmeter to assure adequate voltage for calibration. Charge the battery if necessary.

(B) Fill the impinger with 15 ml of the absorbing solution and place the cellulose membrane filter in the filter holder.

(C) Assemble the sampling train.

(D) Turn the pump on and moisten the inside of the soapbubble meter by immersing the buret in the soap solution and draw bubbles up the inside until they are able to travel the entire buret length without bursting.

(E) Adjust the pump rotameter to provide a flowrate of 1 liter/minute.

(F) Check the water manometer to insure that the pressure drop across the sampling train does not exceed 13 inches of water (1 in. of Hg.).

(G) Start a soapbubble up the buret and, with a stopwatch, measure the time it takes for the bubble to move from one calibration mark to another. For a 1000–ml buret, a convenient calibration volume is 500 ml.

(H) Repeat the procedure in (G) above at least 2 times, average results, and calculate the flowrate by dividing the volume between the preselected marks by the time required for the soapbubble to traverse the distance.

(I) Data for the calibration include the volume measured, elapsed time, pressure drop, air temperature, atmospheric pressure, serial number of the pump, date, and name of the person performing the calibration.

ANALYTICAL

(a) *Principle of the Method.* Sulfur dioxide in the air is absorbed and oxidized in 0.3 N hydrogen peroxide reagent. The pH of the sample solution is adjusted with dilute perchloric acid. After isopropyl alcohol is added bringing the alcohol concentration to approximately 80 percent by volume, the resulting solution is titrated with 0.005 M barium perchlorate using Thorin as the indicator. The endpoint is determined as a change from yellow to pink.

(b) *Range and sensitivity.* The method is sensitive to 0.1 mg sulfur dioxide/cu m of air, assuming a 100 liter air sample. This would correspond to approximately 0.25 ppm of sulfur dioxide in the air. The upper limit is the amount of sulfur dioxide absorbed in the hydrogen peroxide reagent and is at least 5 mg.

(c) *Interferences.* Soluble particulate sulfates and sulfuric acid in the air sample would give erroneously high sulfur dioxide values; however, these can be eliminated by placing an 0.8 micrometer nominal pore size cellulose membrane filter upstream of the impinger in the sampling train.

Metal ion interferences can be eliminated by either the use of the prefilter or, alter-

natively, by passing the solution through an ion exchange column.

Concentrations of phosphate ions greater than any sulfate ion concentration cause appreciable interference. Phosphate can be removed by precipitation with magnesium carbonate. The use of the prefilter should also remove phosphates.

(d) *Accuracy and precision.* At 2.5 ppm, the accuracy is 5 percent with a relative standard deviation of 4 percent. At 25 ppm, the accuracy and relative standard deviation can be improved to about 1 percent.

(e) *Advantages and disadvantages.* The samples are easily collected and conveniently shipped to the laboratory for analysis in glass vials.

The sulfuric acid formed is stable and nonvolatile, making this manner of collection of sulfur dioxide desirable.

The analysis is relatively rapid and simple.

Spillage from the impingers is possible and could be hazardous if spilled into molten metal.

(f) *Apparatus.* (1) Absorber-glass midget impingers.

(2) Personal sampling pump with flow meter capable of sampling at a rate of 1–2 liters/minute.

(3) 37 mm mixed cellulose ester filter, 0.8 micrometer pore size.

(4) Necessary glassware.

(5) A buret of 10 ml capacity graduated in 0.05 ml subdivisions.

(6) Daylight fluorescent lamp aids in identifying the endpoint.

(7) Ion exchange resin—Strongly acidic cation exchange resin, 20–50 mesh, or equivalent. Ion exchange columns may be constructed using glass burets or tubing. A column with an inside diameter of 8 mm and 7 inches of resin has a capacity of approximately 25 milliequivalents.

(g) *Reagents.* (1) Alcohol—isopropanol, reagent grade.

(2) Barium perchlorate, 0.005 M. Dissolve 2.0 g of barium perchlorate trihydrate in 200 ml of water and add 800 ml of isopropanol. Adjust pH to about 3.5 with perchloric acid. Standardize against 0.005 M sulfuric acid.

(3) Thorin—prepare a 0.1–0.2 percent solution in distilled water.

(4) Standard sulfate solution—prepare a 0.005 M solution of sulfuric acid and standardize by titration with 0.005 M sodium hydroxide solution or dissolve 0.7393 g anhydrous sodium sulfate in distilled water and dilute to 1 liter (1 ml=.5 mg sulfur dioxide). The sodium is removed by passage of the standard solution through the ion exchange column.

(5) Hydrochloric acid, 4N—add 300 ml concentrated HCL to 600 ml of distilled water. This is needed only to regenerate the column if the ion exchange procedure is used.

(6) Absorbing solution—hydrogen peroxide, 0.3 N—dilute 17 ml of 30 percent hydrogen peroxide solution to 1 liter with distilled water.

(h) *Procedure.* (1) Cleaning of equipment—the glassware should be chemically clean. Wash in detergent and rinse with tap water and distilled water.

(2) Ion exchange procedure (used to purify standard sulfate solution)—when about two-thirds of the capacity of the resin has been exhausted (deterioration in sharpness of the end point), regenerate the resin by passing 30 ml of 4 N hydrochloric acid through the column. After thorough washing with distilled water, the column is ready for use. Since small volumes of sample solution are passed through the ion exchange column, care must be taken not to dilute the sample with distilled water that remains in the resin. One way this can be accomplished is by forcing air through the resin with a squeeze bulb to remove most of the distilled water from the ion exchange resin. One or 2 ml of sample is passed through the column and is discarded after air is again forced through the resin. The remainder of the sample is then passed through the ion exchange column and an aliquot is titrated according to the general procedure in (1) (3) below.

The column is flushed with distilled water between samples to prevent contamination from the previous sample.

(i) *Analysis of samples.* (1) Measure the volume of the sample solution or dilute it to a given volume.

(2) If high air concentrations of metal ions are encountered which are not completely removed by the prefilter, samples may be passed through the ion exchange column by the procedure detailed in (h) (2) above.

(3) To a 10 ml aliquot, add 40 ml isopropanol. Adjust the pH, if necessary, to between 2.5 and 4.0 with perchloric acid. Add 1–3 drops of Thorin indicator and titrate with barium perchlorate, taking the change from yellow or yellow-orange to pink as the endpoint.

(4) Analyze the standard and absorbing solution blank in the same manner.

(j) *Standardization.* The barium perchlorate solution is standardized by titrating a 5 ml aliquot with 0.005 M sulfuric acid to the endpoint using Thorin as an indicator. The molarity of the solution is calculated as follows:

$$M[\text{barium perchlorate}] = \frac{ml[\text{sulfuric acid}] \times M[\text{sulfuric acid}]}{ml[\text{barium perchlorate}]}$$

Periodic checks of the molarity of the barium perchlorate solution should be run following this same procedure.

If anhydrous sodium sulfate is used to standardize the barium perchlorate, it must first be ion-exchanged since sodium obscures the endpoint. A 5 ml aliquot of the 0.5 mg/ml sulfate solution is ample for standardization.

(k) *Calculations.* The analytical results are calculated on the basis of the following reactions:

SO_2 + hydrogen peroxide = sulfuric acid

H_2SO_4 + barium perchlorate = barium sulfate + 2 perchloric acid

$$\frac{mg[\text{sulfur dioxide}]}{\text{cu m}} = \frac{ml[s] \times M[\text{barium perchlorate}] \times MW}{V[\text{cu m}]} [\text{sulfur dioxide}] \times \frac{V}{V[\text{aliq}]}$$

ml[s]=ml of barium perchlorate solution needed to titrate the sample aliquot minus the blank value.

MW[sulfur dioxide]=molecular weight of sulfur dioxide=64.

V[cu m]=volume of air sampled in cubic meters.

V[aliq]=volume of sample aliquot used for the titration in ml.

V=original volume of sample in impinger in ml.

or

$$\text{sulfur dioxide (ppm) by volume} = ml[s] \times M[\text{barium perchlorate}] \times 24{,}451 \times \frac{V[1]}{V[\text{aliq}]}$$

V[1]=volume of air in liters at 25° C.

24,450=ml/mole that ideal gas occupies at 25° C.

(Secs. 4, 6, 8, 84 Stat. 1592, 1593, 1599 (29 U.S.C. 653, 655, 657) and 29 CFR Part 1911)

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